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Spin Spectrometer at the ALS and APS

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Abstract

A spin-resolving photoelectron spectrometer, the “Spin Spectrometer,” has been designed and built. It has been utilized at both the Advanced Light Source in Berkeley, CA, and the Advanced Photon Source in Argonne, IL. Technical details and an example of experimental results are presented here.

Discussion

Spin resolved photoemission is a powerful technique that includes both energy and spin analysis of the collected photoelectrons. Using the “Spin Spectrometer” (Figures 1-3), our group has used this technique to investigate a number of systems [1- 10], at both the Advanced Light Source [1-6] and the Advanced Photon Source [7-10].

The key measurements are based upon spin-resolving and photon-dichroic photoelectron spectroscopy. True spin-resolution is achieved by the use of a Mini-Mott detection scheme. The photon-dichroic measurements include the variant magnetic x-ray linear dichroism (MXLD). Both a multi-channel, energy dispersive collection scheme as well as the spin-detecting Mini-Mott apparatus are used in data collection. The “Spin Spectrometer” was originally based at the Spectromicroscopy Facility (Beamline 7) at the Advanced Light Source, using linearly polarized x-rays, and subsequently moved to the circularly polarization facility at Beam-line 4 at the Advanced Photon Source. The high angular and energy resolution with high throughput is achieved via the use of an 11-inch mean diameter hemispherical analyzer supplied by Physical Electronics. (Figure 2) Included in this package is an electron collections lens stack with an

adjustable aperture, permitting selection of various angular and sample spot sizes. The novel aspect of our PHI analyzer is that the multi-channel detector has a hole in the center, permitting the direct passage of energy analyzed electrons into the electron optics without resorting to an electron switch yard. [6] The presence of the hole does cause some problems when the multi-channel (non-spin) detection is being used: an increase in dark and background counts. Dark counts are defined as non-zero electron counting that occurs when the multi-channel detection is "on" but no excitation is striking the sample. Background counts are the counts underlying the elastic photoelectron peaks, e.g., a core-level, when actual collection is underway. Regardless, under many conditions, these problems are inconsequential. Spin resolution is achieved by directing the electrons through the optics and into the Mini-Mott detector. In this case, the high voltages on the channel plates are turned off and the channel plates and anode assembly become part of the first lens stack, directing the electrons into the 90° spherical sector. The 90° sector is run at a relatively high pass energy: energy resolution is provided solely by the hemisphere and the photon monochromator. Because the multi-channel detection is at the exit plane of the hemisphere, the imaging of the hemisphere entrance slit onto the multi-channel analyzer is unperturbed and high resolution non-spin counting is achieved. Furthermore, since the spin resolving detection does not require precise imaging, the burden of high resolution spatial imaging is lifted from the 90° sectors. This allows the 90° sectors to be run at high pass energies, optimizing throughput. The 90° sector serves one salient purpose: it allows the simultaneous resolution of both the vertical spin (P_x) and the spin along the electron emission direction (P_z). (Figure 3) These two components are of particular importance in our experiments. After the 90° sector, the electrons travel through another lens stack, into the Mini-Mott detector. In the Mini-Mott, the electrons are accelerated to 24 kV, with four channeltrons positioned horizontally and vertically used for electron counting. While suffering from a relatively low figure of merit, the Mini-Mott has two key advantages to our design. First, it provides essentially turn-key operation with the requirement of no special preparation. Second, it has been

shown that the electron optical matching of a spin detector to a large hemisphere can be optimized by the use of a Mini-Mott.

Finally, an example of our spin resolved data is shown in Figure 4. [11] Note the sharpness of the Fermi Edge and the strong spin-specific nature of individual spectral structures.

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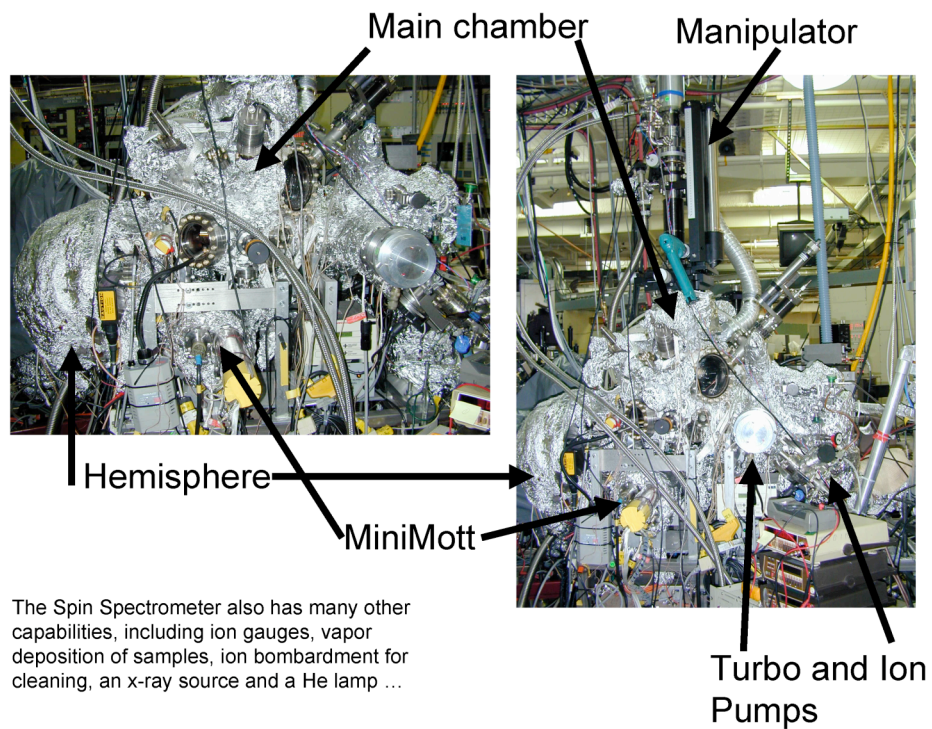


Figure 1

Photographs of the Spin Spectrometer are shown here.

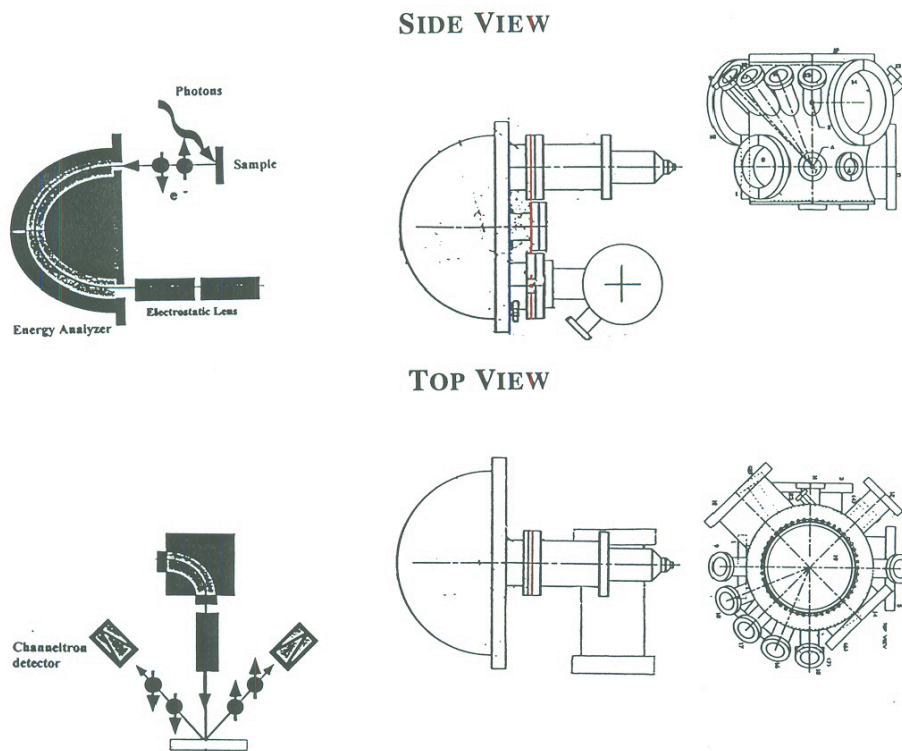


Figure 2

Top and side views of the energy analyzer and vacuum vessel are shown here. The ports include access for LEED, magnetizing coils, evaporation, and sample manipulation. The analyzer has a mean radius of 5.5 inches. The images of the analyzer and vacuum vessel are scaled identically here. The analyzer has an acceptance lens system on the top and the lens stack, 90 degree sector and MiniMott on the bottom.

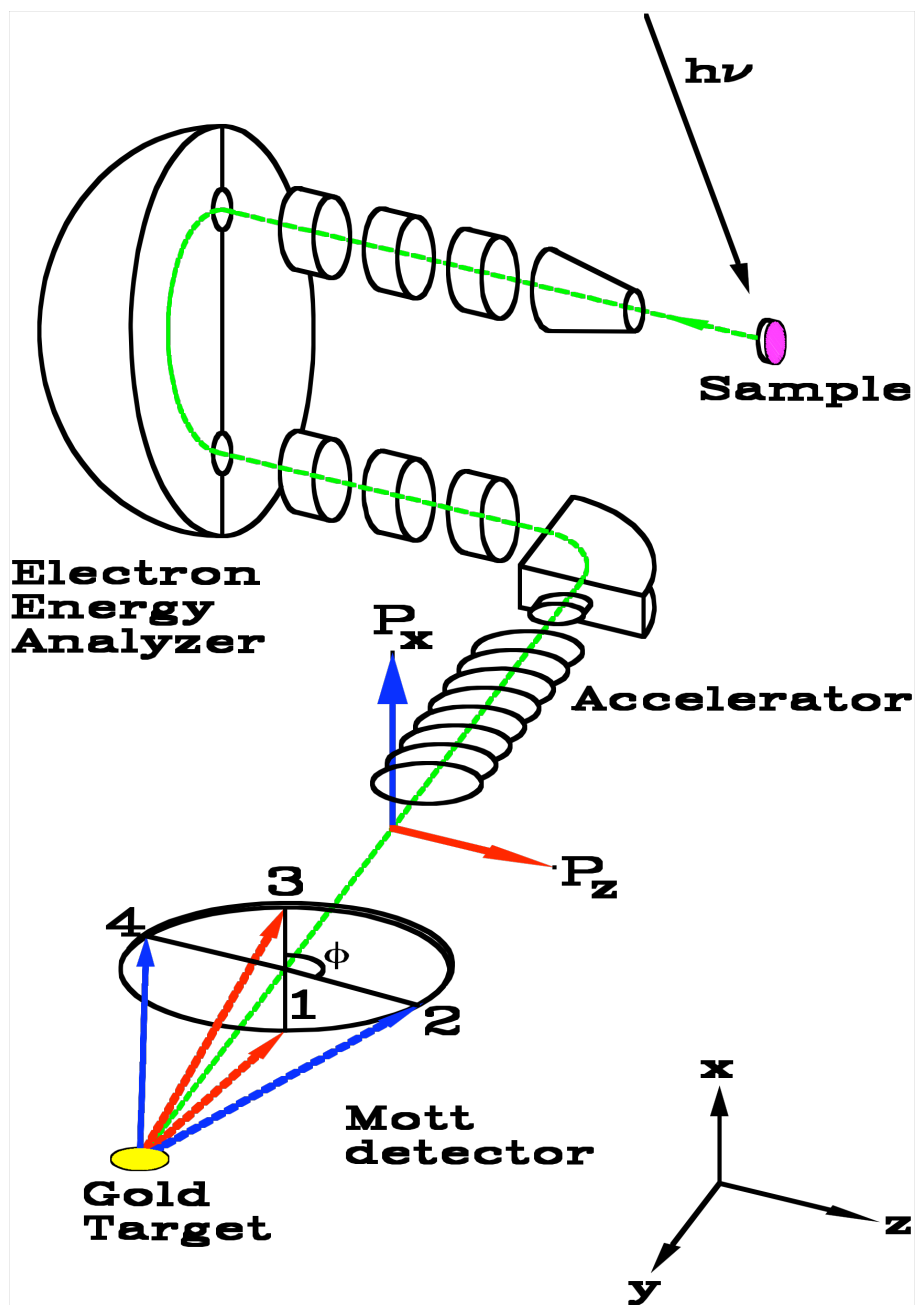


Figure 3
A schematic diagram of the electron analyzer is shown here, including various geometrical relationships.

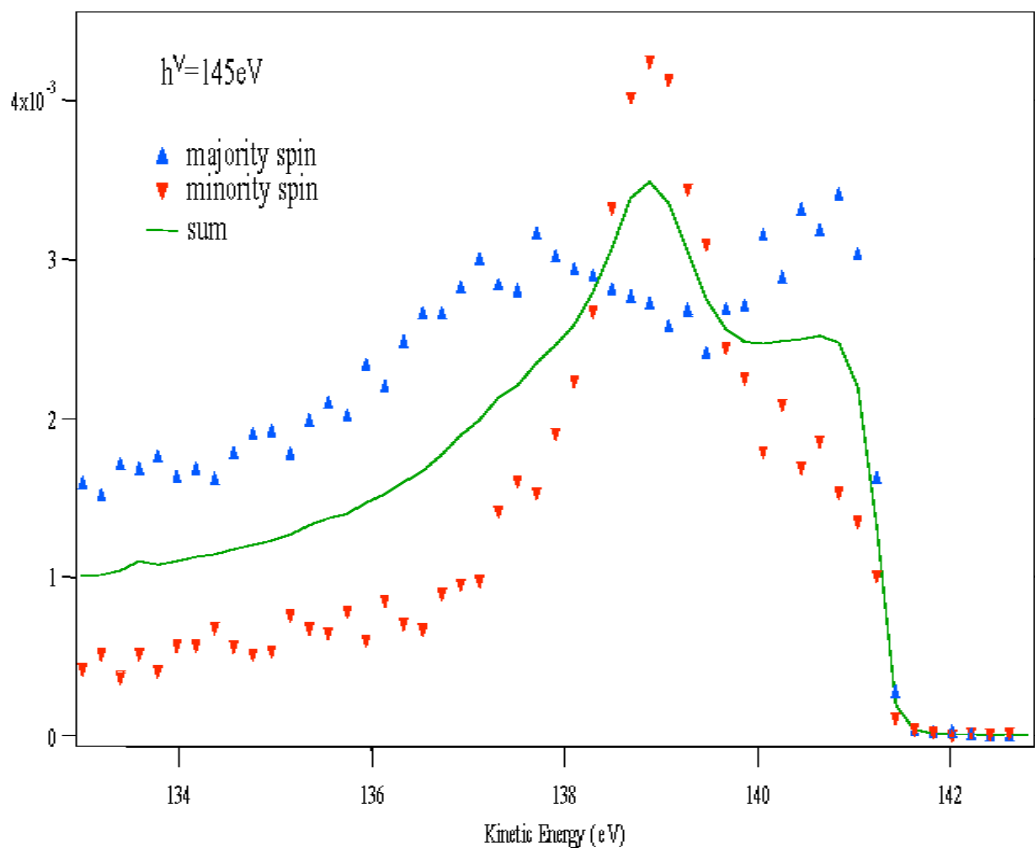


Figure 4

An example of some data collected on Beamline 7 at the ALS is shown here. The photon energy was 145 eV and the photon polarization is linear. The spin-resolved valence band photoemission results are from Fe on GaAs, as part of a larger collaboration. [11] The Fermi edge is near 141 eV Kinetic Energy.